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Evaluating Advancements in Forensic Medicine and Toxicology Through a Scientometric Mapping

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Abstract: The study focused on using scientometric methods to analyze forensic medicine and toxicology literature. The selected period for the study was from 2013 to 2022, allowing for a recent and comprehensive field analysis. The study used bibliographic data from a PubMed database, a widely used biomedical literature database. The study aimed to provide a comprehensive picture of the production and dissemination of the literature in the field. To achieve this, the study analyzed various bibliometric indicators, including theme analysis, keyword evolvement, and collaboration map. The analysis of trending topics and future thematic directions in the field was also conducted to provide insight that could inform and stimulate the research interests of young researchers. This scholarly article explains the construction of author networks, the assessment of author productivity yearly, and the analysis of affiliation networks and organizations. The number of articles published by an institution is an essential indicator of research productivity and expertise in the particular field. The study's findings provided valuable insights into the trends and patterns in forensic medicine and toxicology.

Introduction

Forensic medicine and toxicology are essential fields of study that significantly impact public health and safety. These fields focus on investigating and analyzing substances that can harm human beings, whether natural or synthetic (1). The rise in drug-related deaths and the increasing complexity of new psychoactive substances have made forensic medicine and toxicology even more critical in recent years (2-4). Additionally, forensic medicine plays a vital role in the criminal justice system, providing evidence to help solve crimes and exonerate the innocent (5, 6).

With a vast amount of research being published in forensic medicine and toxicology, keeping track of the trends and characteristics of publications can be challenging. Therefore, scientometric analysis can provide a way to quantify and visualize information, such as frequently used keywords, active authors, and collaboration patterns (7). By conducting a scientometric analysis of publications in these fields, we can better understand the research being conducted, identify potential gaps in knowledge, and improve our overall perception of the current state of these areas of study.

Scientometrics analysis is valuable for gaining insights into research trends and impacts in forensic medicine and toxicology. It involves measuring and analyzing factors such as the number of articles, citation frequency, and collaboration patterns among researchers (8). Through this process, scientometrics can provide a comprehensive understanding of the research landscape in these fields, identify emerging trends, evaluate research impact, and provide insights into the strengths and weaknesses of the field (9, 10). Additionally, scientometrics can help identify research fronts, often viewed as the most innovative and exciting research areas.

Since academic research is one of the most active fields in the world, it is essential to examine current knowledge and practices to identify any gaps that must be filled to advance in any given field (11). Conducting a literature review across various document formats is typically the first step in learning more about a study topic and its current condition. By examining the literature in forensic medicine and toxicology, we can

address fundamental research questions, including the evolution of research in these fields over time regarding academic accomplishments, thematic breakthroughs, academic contributions, and future thematic directions. Additionally, the study aims to identify the nations and dynamic keywords at the forefront of forensic and toxicology research.

Literature Review

For this study, literature reviews provide an overview of scientometric analysis in forensic medicine and toxicology. Kumbar and Biradar (2018) conducted a bibliometric analysis of research articles published in forensic sciences from 2001 to 2015. Their study identified the field's leading countries, organizational affiliations, language, form, and funding agencies. The study's findings provide valuable insights into research trends in forensic science (12).

Jozi and Nourmohammadi (2022) study utilized scientometric analysis to examine the scientific publications and patents in pathology and forensic medicine globally and the citation relationship between them from 2011 to 2020. The study found poor collaboration between academia and industry and highlighted North America as the busiest pathology and forensic medicine region. The study suggested that strengthening the link between academia and industry can enhance research in this field (8). Herve Menard et al. (2021) examined the evolution of research trends within the INTERPOL International Forensic Science Managers Symposium reports over 18 years. References on 10 evidence types were retrieved from the 14th to 19th reports and compared with Scopus citation data. The study investigates the relationships between the 10 evidence types and provides a comprehensive overview of trends in forensic science research. A user-friendly R-Shiny application was also developed to explore the study outputs (12).

Materials and Methods

A comprehensive systematic mapping assessment of the forensic medicine and toxicology literature in the PubMed database constituted a component of the analysis. The study used R-Studio version 1.2.5033 developed by RStudio, PBC, located in Boston, Massachusetts, United States of America. Biblioshiny, a user-friendly web-based application that allows for the visualization and exploration of bibliometric data, was used. The latest version of Biblioshiny available on the Comprehensive R Archive Network (CRAN) was 0.4.0, released on March 2, 2021. The VOSviewer software tool, which the Centre develops for Science and Technology Studies (CWTS) at Leiden University in the Netherlands, was applied in this study for constructing and visualizing bibliometric networks (13). The current version of VOSviewer, 1.6.17, was used for this study. The application provides interactive tools that enable users to analyze research trends, identify leading authors, institutions, and countries in a particular field, and visualize co-authorship networks and citation relationships programmed to retrieve data from PubMed using R-based packages. Information was gathered using the string shown below.

In this study, the PubMed database is considered because it is a widely used and trusted database in the medical and scientific community. It is a specialized database managed by the National Library of Medicine (NLM) and provides access to a vast collection of biomedical literature, including research articles, books, and reports (14). PubMed has a comprehensive indexing system that allows for easy searching and retrieval of relevant literature, making it a valuable resource for researchers and healthcare professionals. Moreover, PubMed is freely accessible to the public, and it provides an up-to-date and reliable source of information for individuals interested in health-related topics. The database is regularly updated, ensuring the latest research and findings are available to its users.

The search strategy used a combination of search terms and filters to find journal articles related to forensic medicine and toxicology published in English between January 1, 2013, and December 31, 2022. The search strategy starts with the Medical Subject Headings (MeSH) term "forensic medicine" or any instances of the terms "forensic" and "medicine" appearing in the title, abstract, or text of the article. The search was then refined to include articles that specifically mention "toxicology" in the title or abstract and are published in English. The following are the search keyword used:

("forensic medicine"[MeSH Terms] OR ("forensic"[All Fields] AND "medicine"[All Fields]) OR "forensic medicine"[All Fields]) AND "and toxicology"[Title/Abstract] AND "english"[Language] AND "journal article"[Publication Type] AND 2013/01/01:2022/12/31[Date - Publication]

Data Analysis and Discussion

From 2013 to 2022, 653 authors and 133 documents were in the published records extracted from 75 sources. 13.76% growth rate annually, and 5.72 is the average years of age of the documents. During this time, 133 works of literature were published, equivalent to 113 published articles, 4 comparative studies, 1 clinical trial, and 15 case reports. "Single-authored docs" and "Co-Authors per Doc " refer to the average number of authors per document. Table 1 and Figure 1 shows the collected literature characteristics and production.

The years 2016, 2020, and 2021 saw a rise in the

prominence of literature in forensic medicine and toxicology. When forensic medicine and toxicology papers were examined in the PubMed database, it was discovered that the top three journals were the Journal of Forensic and Legal Medicine, the International Journal of Legal Medicine, and Forensic Science International.

Table 1. Data characteristics of literature collection.

Description	Results
Main information about data	
Timespan	2013 - 2022
Sources (Journals, Books, etc)	75
Documents	133
Annual Growth Rate %	13.43
Document Average Age	5.72
Average citations per doc	0
References	1
Document contents	
Keywords Plus (ID)	507
Author's Keywords (DE)	398
Authors	
Authors	635
Authors of single-authored docs	5
Authors collaboration	
Single-authored docs	5
Co-Authors per Doc	5.61
International co-authorships %	0
Document types	
Case reports	15
Clinical trial	1
Comparative study	4
Research article	113

The Journal of Forensic and Legal Medicine is a peer-reviewed academic journal that publishes original research articles, case reports, and reviews related to forensic medicine, forensic science, and legal medicine. The journal was first published in 1994 and is currently published by Elsevier (15). According to the 2020 Journal Citation Reports (JCR) by Clarivate Analytics, the journal has an impact factor of 1.717, ranking it 46th out of 92 journals in the category of forensic sciences. The Journal of Forensic and Legal Medicine is positioned in the second quartile for the %Tier metric, which evaluates the percentage of journals within a category with an impact factor equal to or greater than the journal under scrutiny, with a score of 44.57%.

Based on Scopus, a scholarly literature database, the journal has garnered 4,170 citations since it was established and had an h-index of 37 (16). The h-index aims to evaluate the productivity and impact of a scholar or researcher's publications by considering the number of publications and citations they have received. The Journal of Forensic and Legal Medicine is respected and vital in forensic medicine and forensic science, with a relatively high impact factor and many citations. Its prominence can also be seen because it was among the top three journals in forensic medicine and toxicology, as identified by examining papers in the PubMed database.

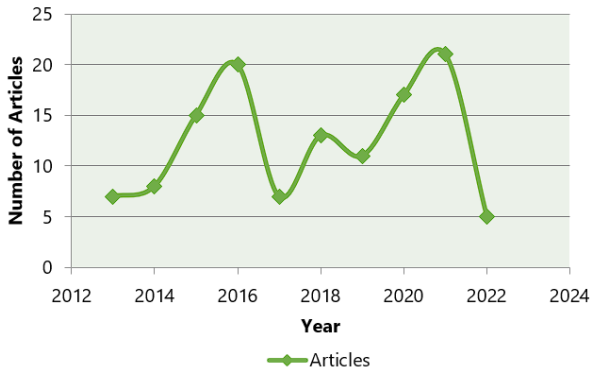

Figure 1. Literature production in the field of forensic medicine and toxicology.

The International Journal of Legal Medicine and Forensic Science International are highly respected and influential peer-reviewed academic journals covering topics related to forensic medicine, forensic science, and legal medicine. The International Journal of Legal Medicine has an impact factor of 2.204 and a % Tier score of 55.43%, indicating that it is a well-respected and widely read journal in the field. Forensic Science International has a higher impact factor of 2.842, a % Tier score of 63.04%, and a total of 63,486 citations, indicating that it is more widely read and cited in the field (17). However, both journals are important sources of research and scholarship in forensic medicine and forensic science. Figure 2 shows the number of articles published in several journals.

An essential approach for determining hot subjects and academic focus in an area is the analysis of keywords used by authors in publications. For word cluster, biblioshiny software displays frequently used terms in toxicology and forensic medicine publications.

Theme Analysis

A trending topic analysis was performed using the keyword plus in bibliophily. The study was conducted with the following settings: 2013 to 2022. Thematic evolution in forensic and toxicology is important for understanding the field's current state and identifying key issues and challenges, as well as emerging trends and future directions for research.

Keyword centrality is a measure used in

scientometric analysis to assess the importance and frequency of a specific keyword in a corpus of scientific literature. Keyword centrality provides a useful tool for exploring the structure and content of a specific field of study (18). It can help to identify the most important topics and themes in a field, as well as the most prominent authors and institutions. Keyword centrality can also help to identify the relationships between different topics and themes in a field and to identify trends and changes over time (19).

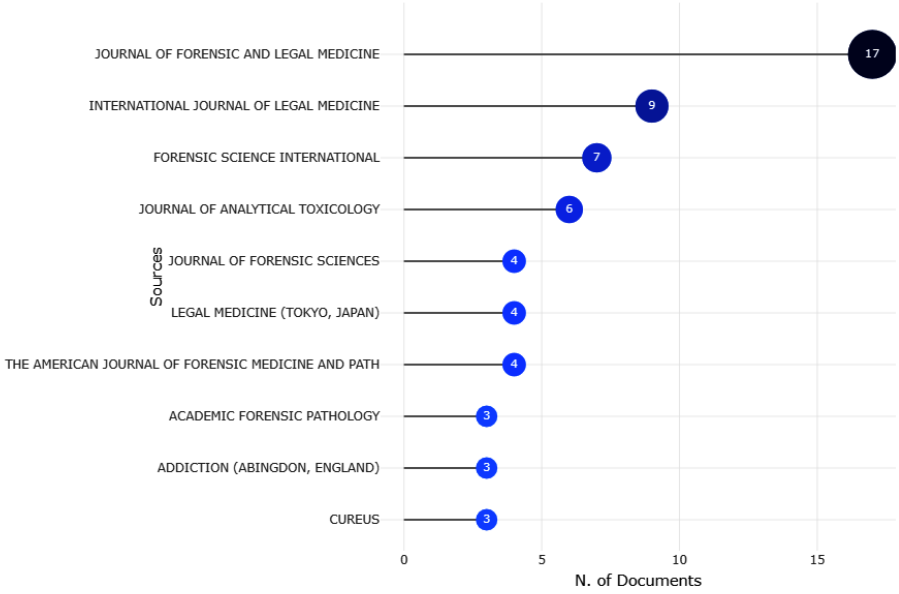

Figure 2. Top cited journals in forensic medicine and toxicology.

The words were grouped into clusters, and each was assigned a label. The Figure 3 includes three centrality measures for each cluster: betweenness centrality, closeness centrality, and PageRank centrality. Betweenness centrality measures how often a cluster acts as a bridge between other clusters. Closeness centrality measures how close a cluster is to all other clusters. PageRank centrality is a measure of the influence of a cluster in the network of clusters (20).

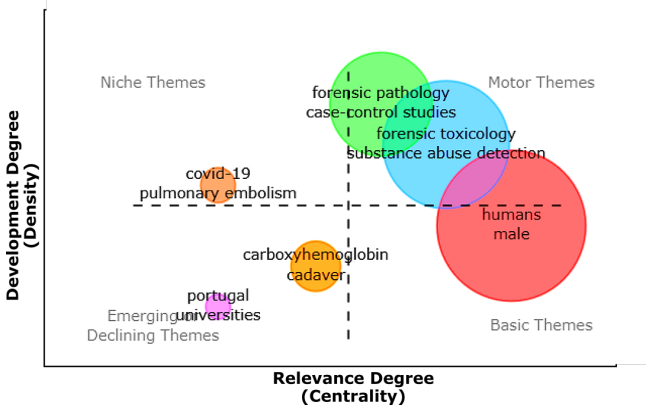

Figure 3. Theme exploration in forensic medicine and toxicology.

The overarching theme for all the words in this study is "humans," which is a popular topic. "Humans" also has the highest betweenness centrality value, indicating that it plays a crucial role in connecting other terms in the network. The word "male" is the most central, highlighting its close relationship with other terms in the graph. Additionally, according to PageRank centrality values, "humans" and "male" are the most important terms in terms of their impact on other terms in the network. The findings are in accordance with the previous study showing a high frequency of human, specially males, being pronounciated (21).

Regarding individual word analysis, "forensic toxicology" stands out with a high CallonDensity and CallonCentrality, indicating its significant stimulus and interconnectedness with other words. "Forensic pathology" has a high CallonDensity, emphasizing its connections with other words. On the other hand, "Portugal" and “University” has low RankCentrality and RankDensity values, implying that it is not very effective or connected within the dataset. "Carboxyhemoglobin" and "Covid-19" also have low CallonCentrality and RankCentrality values, suggesting their limited impact and connections within the network. From the information, a researcher can identify the most critical and dominant terms related to their research topic and less important or less frequently occurring terms. This can help focus on the key research areas and prioritize the crucial terms for further investigation.

For researchers, this type of analysis can help identify important topics or themes within a particular

field of study and areas that may be less well-connected or under-explored. By understanding the relative importance and centrality of different concepts, researchers can prioritize their efforts and focus on areas likely to have a greater impact on their field. Additionally, this analysis can track trends and changes over time, allowing researchers to identify emerging areas of interest and track the evolution of different concepts and ideas. By staying up-to-date on these trends and changes, researchers can position themselves to make important contributions to their field and stay at the forefront of new developments. Overall, using centrality and density metrics in analyzing large datasets can provide valuable insights for researchers, helping them identify important themes and trends and focus their efforts on areas likely to have the greatest control (22). Figure 4 shows the frequency of various words that occur in publication over the years. 'Human', 'Male', and 'Female' are the top words mentioned in the literature.

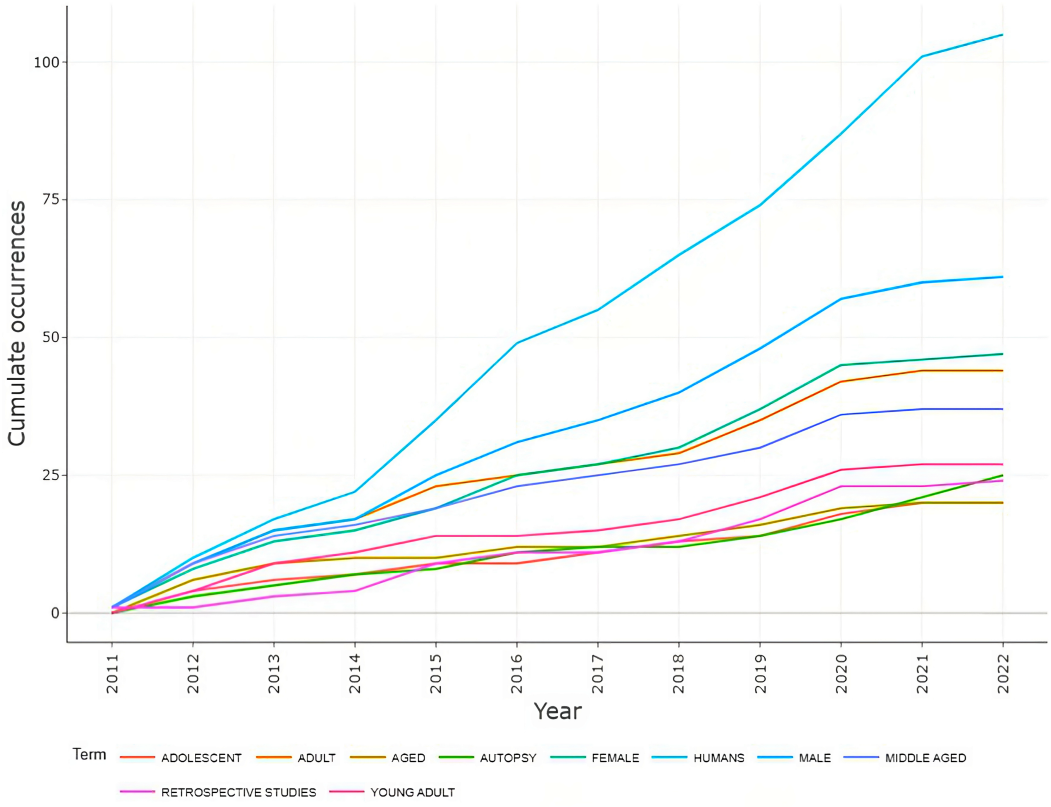

Figure 4. Keywords evolvements over the time.

Collaboration World Map

'Country collaborations' studies academics from various nations' co-authorship, citation, and publishing habits (23). Science mapping offers a method to measure and examine the connections between researchers, institutions, and nations in creating and exchanging information. By examining national collaboration, one can learn more about the internationalization of science, the sharing of knowledge across international boundaries in the fields of forensic science and toxicology, and the effects of global collaboration on the output and influence of science (24).

Italy and USA collaborated most with other countries, with Italy collaborating with Switzerland, Finland, Denmark, France, Germany, Hungary, Ireland, Portugal, Russia, and the USA. In contrast, the USA collaborates with Australia, Canada, Norway, and Sweden. Germany collaborates with other countries, including Bulgaria, Estonia, Finland, France, Hungary, Ireland, and the Netherlands. Other countries collaborating with other countries include Australia, Denmark, Egypt, Estonia, Finland, France, Greece, India, Portugal, Saudi Arabia, Switzerland, and Turkey. The most frequent collaborations are between Italy and Switzerland and between the USA and Sweden, with a frequency of 3. Collaborations between Saudi Arabia and Egypt, as well as between Sweden and Canada, are the least frequent, with only one occurrence.

Author Productivity Over the Years

Figure 5 provides the frequency of publications and the total number of citations for a group of authors. The authors have been ranked in descending order based on the total number of citations received for their publications. The top ten authors in this list are Athanaselis S, Nikou C, Spiliopoulou C, Papoutsis I,

Katelou M, Dinis-Oliveira RJ, Bardy D, Nikolaou P, Palmiere C, and Darke S.Analyzing figure. It is observed that the majority of these top authors have published their work in the last decade. The most recent year for which data is available in the table is 2022, and it can be seen that Spiliopoulou C is the only author who has published this year. Spiliopoulou C has been very active recently, with six publications since 2014, the highest among the top ten authors.

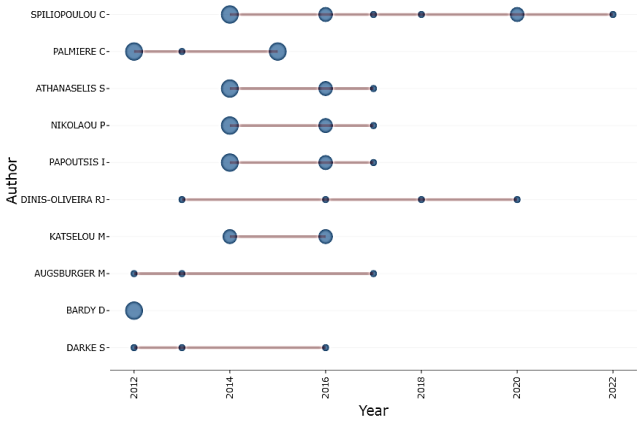

Figure 5. Author's productivity over the years.

Another observation is that some authors have published their work in bursts. For example, Athanaselis S has published only six papers in the last ten years, but three were published in 2014 alone. Similarly, Palmiere C published seven papers between 2012 and 2015 and only one paper after that. Regarding citation counts, Nikou C and Spiliopoulou C stand out as the authors with the highest number of citations. Interestingly, Nikou C has a higher citation count despite having fewer publications than Spiliopoulou C. This may indicate that Nikou C's work is more impactful and prominent in the research community.

This author analysis provides a glimpse into a group of authors' publishing and citation patterns. It shows that while some authors have consistently published over the years, others have published their work in bursts. Additionally, citation counts can vary widely among authors, even those with similar publication counts. The authors' research impact on the scientific community can be demonstrated by their publications and citations, suggesting that their work is being acknowledged and utilized by their peers in the field (25). This can lead to further collaborations and advancements in forensic medicine and toxicology.

Bibliography Coupling by Author Collaborations

The graph depicted in Figure 6 portrays an intricate network of authorship details associated with a research article, delving into the multiple dimensions of authorship that contribute to the success of a research endeavor. PubMed data yielded 635 authors, extracted to map their link strength, and published at least one document.

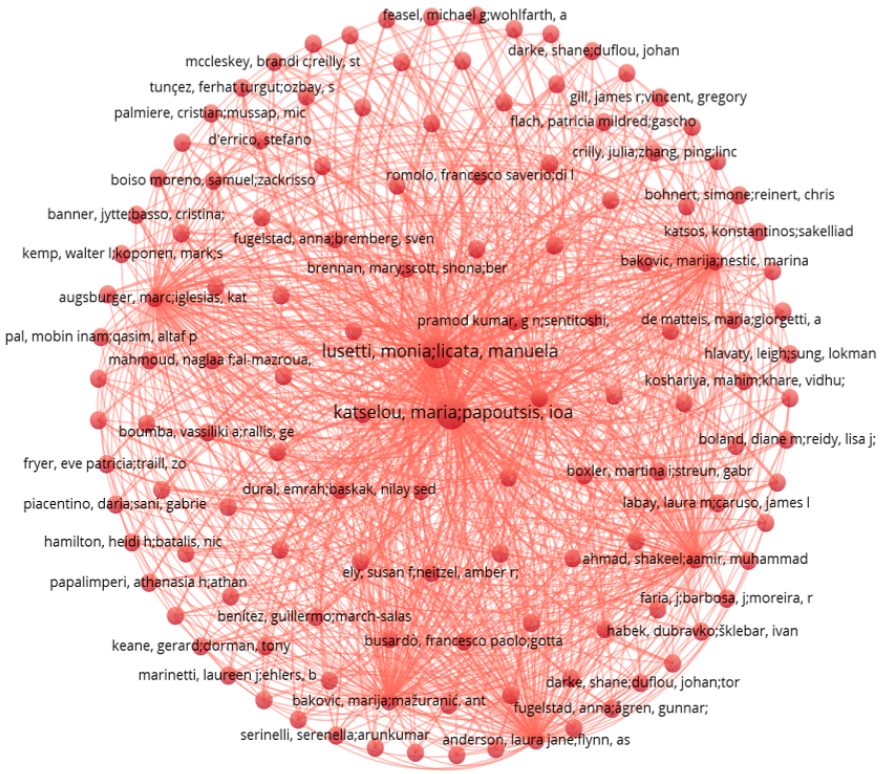

Figure 6. Authors' collaboration network in forensic medicine and toxicology.

The data comprises a diverse range of authors, each with their corresponding number of documents, citations, and total link strength, adding to the complexity and depth of the findings presented. The first group of authors, namely Ahmad Shakeel, Aamir Muhammad, Kirmani Sobia Irum, Haroon Zujaja Hina, Bibi Afshan, and Khalid Usama Bin, have contributed to the research article with a single document that boasts total link strength of 133. Similarly, the second group of authors, comprising Laura Jane Anderson, Asher Flynn, and Jennifer Lucinda Pilgrim, have made an equal contribution with total link strength of 133, lending credence to the notion that research success can be achieved even with minimal input from multiple contributors.

The third group of authors, Puneet Arora, Ashok Chanana, and Hakumat R Tejpal, have published a single document and have total link strength of 133, further adding to the dynamic nature of research authorship. The fourth group of authors, which includes Marc Augsburger, Katia Iglesias, Daniel Bardy, Patrice Mangin, and Cristian Palmiere, have published one document with a total link strength of 133, providing evidence of the collaborative nature of scientific research. The fifth group of authors, Marija Bakovic, Anton Mažuranić, Vedrana Petrovecki, and Davor Mayer, have published a document with a total link strength of 133.

In contrast, the sixth group, Marija Bakovic, Marina Nestic, and Davor Mayer, has identical publishing statistics. The seventh author group, Ali Banagozar Mohammadi, Maryam Zaare Nahandi, Ali Ostadi, Anahita Ghorbani, and Shahin Hallaj, has contributed one document to the research article with a total link strength of 133, highlighting the collaborative efforts of authors towards scientific progress. The eighth group of authors, Jytte Banner, Cristina Basso, Zoe Tolkien, Ivana Kholova, Katarzyna Michaud, and Patrick J Gallagher, has also published one document with a total link strength of 133, indicating the vital role played by a diverse range of experts in the research process.

Lastly, the ninth group of authors, including Elan Barenholtz, Alex J Krotulski, Paul Morris, Nicole D Fitzgerald, Austin Le, Donna M Papsun, Barry K Logan, William E Hahn, Bruce A Goldberger, Linda B Cottler, Joseph J Palamar, has also contributed one document with a total link strength of 133, further underscoring the complex nature of authorship and its contribution to scientific progress. Besides, the study includes authors, namely Behera Chittaranjan, Singh Prashasti, Shukla Prachi, Bharti Deepak R, Kaushik Ruchika, Sharma Nidhi, Mahapatra Braja Kishore, Chauhan Kamal, Meher Sushil Kumar, Yadav Abhishek, Tabin Millo, Gupta Sudhir Kumar, and Singh Harpreet. Their collective work resulted in one document with total link strength of 133.

The rich and varied data presented in the map the intricate nature of scientific research and the vital role played by a diverse range of experts in the process. The information presented in the table has the potential to serve as a valuable resource for scholars and researchers interested in exploring the dynamic interplay between authorship, citations, and link strength in scientific research.

Affiliation Wise Publications

The present analysis has examined the publication output of various academic and research institutions specializing in forensic medicine and toxicology. This investigation reveals that the Department of Forensic Medicine and Toxicology, situated in the Faculty of Medicine, National and Kapodistrian University of Athens, Greece, has published the most articles, amounting to 16, in the dataset under scrutiny. Following closely behind, the Shanghai Key Laboratory of Forensic Medicine, Shanghai Forensic Service Platform, Academy of Forensic Sciences, Ministry of Justice, Shanghai, China, has published 11 articles. The European Council of Legal Medicine Board, located in Cologne, Germany, has contributed 10 publications to the dataset. In contrast, the Department of Legal Medicine, Graduate School of Medicine, Chiba University, Japan, has produced 9 articles. The Department of Forensic Medicine and Toxicology, AIIMS, New Delhi, India, and the Department of Forensic Toxicology, Shanghai Key Laboratory of Forensic Medicine, Shanghai Forensic Service Platform, Academy of Forensic Science, Shanghai, China, both share the distinction of publishing 8 articles.

Moreover, the Department of Medical and Surgical Sciences, Unit of Legal Medicine, University of Bologna, Italy, and Hillsborough County Medical Examiner Department, Tampa, FL, USA, have each published 8 and 7 articles, respectively. Finally, the Melbourne School of Population and Global Health, The University of Melbourne, Justice Health Unit, Australia, and the Department of Forensic Medicine, Graduate School of Medicine, The University of Tokyo, Japan, have each contributed 7 and 6 articles to the dataset, respectively. The number of articles published by an affiliation serves as a proxy for their research productivity and expertise in forensic medicine and toxicology.

Figure 7 presents the results of a scientometric analysis, which examines the publication and citation patterns of various research organizations in forensic and toxicology and related disciplines. The figure includes the organization's name, the number of documents published, the number of citations received, and the total link strength. Link strength represents the degree of collaboration between

organizations, as measured by the co-authorship of publications.

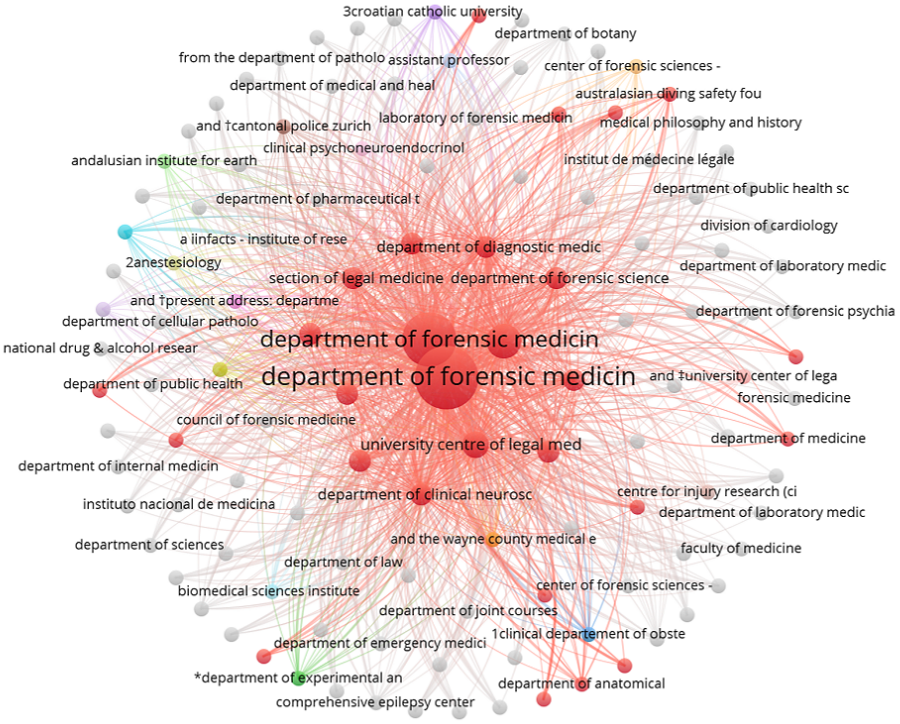

Figure 7. Department collaboration network in forensic medicine and toxicology.

Among the organizations listed, the Department of Experimental and Clinical Toxicology appears to have the highest link strength, totaling 162. The Clinical Department of Obstetrics and Gynecology at the Clinical Hospital "Sveti Duh" in Zagreb, the Department of Forensic Genetics and Forensic Toxicology, the Anesthesiology Department, the Croatian Catholic University in Zagreb, the INFANTS - Institute of Research and Advanced Training in Health Sciences and Technologies, the Institute of Forensic Medicine and Criminalistics, the Wayne County Medical Examiner's Office, and the Cantonal Police Zurich all have a link strength of 162.

This analysis provides insights into the collaboration patterns among research organizations in toxicology. This information can be used to promote future collaborations and knowledge sharing by identifying the organizations with the highest link strength. It can also serve as a useful tool for evaluating the productivity and impact of research organizations in toxicology.

Limitations and Scopes

The limitations of this study are that the scientometrics data used may not fully represent all the relevant literature in the field of forensic medicine and toxicology, as it is limited to the chosen database in this study, PubMed. Additionally, scientometric methods may not account for all factors that contribute to the quality or impact of research, such as the societal or practical implications of the findings. The study's focus on identifying trending topics and future directions may also overlook important topics or areas of research that do not fit within these categories. Finally, the study's reliance on scientometric analysis may limit the interpretation of results and may not fully capture the nuances and complexities of the field. The future scope of a study analyzing forensic medicine and toxicology literature using scientometric methods could involve several potential directions. Some possibilities include:

1. Expansion to additional databases: Future studies could expand beyond the current database and include other relevant bibliographic data sources, such as grey literature or non-English language publications.
2. Comparison across fields: Comparative scientometric analyses could be conducted to compare the trends and patterns in forensic medicine and toxicology to other related fields, such as pathology, toxicology, or epidemiology.
3. Incorporation of other metrics: Additional metrics beyond scientometric methods could be incorporated into the analysis to provide a more comprehensive picture of the impact and influence of research in the field, such as policy impact or public engagement metrics.

4. Exploration of interdisciplinary collaborations: Future studies could explore the extent and impact of interdisciplinary collaborations within forensic medicine and toxicology and potential opportunities for further interdisciplinary research.
5. Investigation of ethical considerations: Future studies could investigate ethical considerations associated with the production and dissemination of research in forensic medicine and toxicology, such as consent and confidentiality issues, and how these may impact the scientometric analysis of research in the field.

Conclusion

This study emphasizes how, in terms of conceptual advancements and scholarly contributions, forensic medicine and toxicology fields have changed through time. The study identified several areas, including humans, Carboxyhemoglobin, Forensic pathology, etc., which may help young researchers decide what areas of study to pursue. The study also employed scientometric analysis methods to pinpoint the most weighty nations and institutions in toxicology and forensic medicine. Overall, this study's findings offer insightful information on the shifting boundaries and new trends in forensic medicine and toxicology, which could have significant Ideas for researchers.

Declarations

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Conflict of Interest

The authors declare no conflicting interest.

Data Availability

The unpublished data is available upon request to the corresponding author.

Ethics Statement

Not applicable.

Funding Information

Not applicable.

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